African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 3, Issue 4, 2020 (pp. 1-11)
www.abjournals.org

# CHARACTERIZATION OF OILY WASTEWATER KEY TO PROPER DESIGN AND MAINTENANCE OF OILY WASTE WATER SEPARATORS - A CASE STUDY OF NIGER DELTA REGION

**Onyenanu Chukwunonso and Nwokoye Christian U.**

Chemical Engineering Department, Nnamdi Azikiwe University, Awka. Anambra State, Pollution Control /QAQC Engineer PortHarcourt.

**ABSTRACT:** *Environmental regulation of oily waste water discharges are becoming more stringent. Oil industrial facilities have a number of possible applications for coalescing plate separators. These applications include flow stations, tank farms, process drains, Shipboard oily wastewater and runoff from oil spills. In recent years, it has become obvious that many of the oily waste water separators installed in the oily waste water facilities are not performing as anticipated. Several authors have pointed out the need to improve the design procedure of oil-water separator. The issues arising from poor design, improper selection of pre-manufactured off- the-shelf coalescing unit attributed to failure of understanding the character of oily waste waters being treated or pretreated. The sampling station investigated consist of three effluent receiving sites in the okrika arm of the Bonny River and the control sites at Elechi creek, all in the Niger Delta area. The result of characterization showed that maximum and minimum Temperatures are 20 and 18.31$^0$C, Specific gravity of waste water at maximum and minimum temperature are 0.994 and 0.986. Also specific gravity of oil in the waste water at maximum and minimum temperature are 0.873 and 0.845 while dynamic viscosity of oil waste water at maximum and minimum temperature are 0.00127 and 0.00132 N/m$^2$.s. Also physico chemical characteristics at maximum and minimum values showed that pH are( 8.80 and 8.50), Conductivity (215.0 and 214.0 µS/cm), Total dissolved solid ( 165.50 and 159.58 mg/l), Total suspended solid ( 64.41and 61.79 mg/l), Salinity as Chloride ( 40.13 and 37.46 mg/l) while oil and grease ( 46.80 and 41.40 mg/l) Biological Oxygen demand ( 31.00 and 28.83 mg/l) and Chemical Oxygen demand (43.53 and 40.21 mg/l) . This characterization is useful in overall design, sizing of oily wastewater separator and separation efficiency.*

**KEYWORDS:** Characterization, Design, Maintancence, Efficiency, Oily Waste Water

## INTRODUCTION

Oily wastewater quality can be defined by physical, chemical, and biological characteristics, but only physic-chemical properties will be discussed in this paper. Physical parameters include color, odor, temperature, solids (residues), turbidity, oil, and grease. Solids can be further classified into suspended and dissolved solids (size and settleability) as well as organic (volatile) and inorganic (fixed) fractions. Chemical parameters associated with the organic content of wastewater include the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). BOD is a measure of the organics present in the water, determined by measuring the oxygen necessary to biostabilize the organics (the oxygen equivalent of the biodegradable organics present).

Inorganic chemical parameters include salinity, hardness, pH, acidity, alkalinity and others APHA, (2015). Design considerations for wastewater treatment facilities are based in part on the characteristics of the wastewater. The most important pollutants in the crude oil processing wastewater and oil spill runoff are conventional pollutants such as oil and grease, suspended solids and pH, and non-conventional pollutants such as phenolic compounds, COD, sulfide and ammonia APHA (2015). Among these, oil and grease are one of the most complicated pollutants to remove.

Oil and grease cause significant long-term harm to the environment if discharged untreated. It can also plug and foul sewer system causing significant maintenance problems if they are not removed from waste water. Also, it had a detrimental impact on subsequent wastewater treatment processes if not properly controlled. Significant efforts have been made to regulate pollution in most industrialized countries and the stringency of pollution regulations has continued to increase worldwide Managi et al, (2015), Mohr et al, (2000) ) stated that Governments around the world have been working towards protecting the environment by enacting and enforcing laws regarding hydrocarbon discharges.

Not all oily wastewater is the same. Understanding the source, nature and characteristics oil wastewater is key to understanding how to treat it. Once the characteristics of the oily wastewater are understood, the proper oil-water separation technology can be selected (Tom Schultz, 2011). Oily wastewater varies greatly- petroleum production, petroleum refining, petrochemicals and storm water runoff. Oil-water separators are used to separate it and its products from water in the petroleum, chemical and other industries Ashraf et al, (2015) Once you know the source of oily wastewater, understand the characteristics of the oil and other constituents in the wastewater which may include- specific gravity of the oil and grease to be separated, viscosity of the oil and grease, free oil and grease concentration in the raw wastewater, total oil and grease concentration in the raw wastewater. Design of coalescing oil-water separator systems requires proper characterization of the wastewater, establishment of the design flow and required effluent quality, sizing of the separator, and proper flow attenuation/flow equalization of the influent. Characterization oily wastewater to be treated should be analyzed for total oil and grease, including determination of the free, emulsified, and dissolved oil fractions. Although oil-water separators are designed to remove free oil, they also remove solids. APHA, (2015)

The purpose of this paper is to characterize oil waste water which will serve as reference purpose for designing of oil wastewater separation system in Niger Delta region that will meet the requirements for treating oil wastewaters.

## MATERIALS AND METHODS

### Description of the Study Area

The sampling stations investigated consist of three effluent receiving sites in the Okrika arm of the Bonny River and the control site at Elechi Creek, all in the Niger Delta area. Sampling site I ($X_1$), Ekerikana creek, is the effluent discharge point. Sampling sites II ($X_2$), Okari Creek, and III ($X_3$), Okrika flow station, are located 500 m and 1000 m respectively from sampling site I.

### Sample collection

Samples were collected once a month between January 2018 and December 2018. Composite water samples (sub-surface and middle depth) were collected at low tide with a 2 litre plastic hydrobios water sampler and transferred to clean 2-liter polyethylene containers and 250 ml capacity borosilicate glass bottles. These were collected in polyethylene containers and borosilicate bottles of the same capacity. They were rinsed several times with water or effluent samples at the point of collection the samples were transported in ice chests and analyzed for pH and conductivity within 12 hours of collection. Other physicochemical parameters were analyzed later using refrigerated samples.

## METHODOLOGIES

The methodologies employed for analysis were in accordance with the Department of Petroleum Resources DPR (2002) Environment Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN), Revised Edition and other international standards.

### Test for Specific Gravity of Oil and Water in Wastewater Sample

The following procedure is used to test for the specific gravity of oil and water in wastewater API, (2005).

a. Representative samples of the entire waste flow were taken.

b. Agglomerates of the oil were broken to release the oil, and the sample stood for one hour in other to settle.

c. Oil that gathered on the water's surface were collected and centrifuged, then oil and water specific gravity were measured using hydrometer

d. When enough data have been collected to establish a specific gravity of oil and water in wastewater: range of specific gravities, the upper limit of the range is the design value for specific gravities were recorded.

e. Also, water viscosity was recorded using viscometer

### In-Situ Analysis for Physico Chemical Parameters

Unstable parameters such as pH, TDS, Conductivity and temperature were analyzed in-situ on the Field. Results of such analysis were recorded in the field log book duly attested to by the sampler.

### pH APHA 4500 H

pH value indicates the acidic, neutral or alkaline nature of a liquid. The pH values range from 0 (very acidic) to 14 (very alkaline) with a pH 7 being neutral. Measurements were carried out by means of Joneyway pH meter, which had been previously calibrated in the laboratory. Calibration was checked on the field by measuring standard buffer solutions. Calibration was repeated if reading was more than +/-5% of expected reading.

**Temperature**

This was determined by means of a mercury thermometer calibrated in $0.2^0$C units from $0^o$C to $100^o$C. The thermometer was dipped into the sample and left for about 5minutes for equilibration before the reading was recorded.

**Total Dissolved Solids (TDS)**

Wastewater contains a variety of minerals or salts, which are mainly composed of carbonates, bicarbonates, chlorides and nitrates. TDS is a measure of the total combination of all these minerals and salts. TDS was determined according to APHA-2540-C (Department of Petroleum Resources (DPR), (2002

**Total Suspended Solids (APHA 2540-D)**

This was determined by filtering a well-mixed aliquot (100-ml) of the sample through a dried and pre-weighed Millipore filter paper using vacuum filtration apparatus. The filter paper was then dried at $105^0$C to constant weight. The difference in weight of the filter paper represents the total suspended solids. This was reported in mg/l after calculation APHA, (2015)

**Salinity (Chloride) (APHA 4500-B)**

Salinity as chloride was determined using the Mohr's method as described in APHA 4500-B. The titration method is based on the reaction of silver with chloride ions using potassium chromate as indicator. Silver chloride is precipitated quantitatively before red silver chromate is formed. Salinity as chloride is reported in mg/l after calculations.

**Chemical Oxygen Demand (APHA 5220 B)**

Chemical Oxygen Demand (COD) was used as a measure of the oxygen equivalent of the organic matter content of the sample, which is susceptible to oxidation, by a strong chemical oxidant. COD was determined using the open reflux method APHA, (2015), where a sample is refluxed and digested in a strongly acidic solution with a known amount of excess of potassium dichromate (k2Cr2O7). After digestion, the excess un-reacted potassium dichromate was read with a spectrophotometer at 600-nm and results were reported in mg/l. Results were also verified by titrating with a standard solution of ferrous ammonium sulphate.

**Biochemical Oxygen Demand APHA 5210B**

BOD5, which depends on oxygen uptake by bacteria, was determined using the dilution method according to APHA 5210B APHA, (2015). The amount of oxygen consumed during a fixed period (usually 5 days) is related to the amount of organic matter present in the original sample. Dissolved oxygen of the samples was first determined using the Dissolved Oxygen meter and then incubated for five (5) days at $20^o$C. DO was again measured after a period of five days and BOD in mg/l was determined from the following calculation and reported accordingly.

**Thc (Oil and Grease) (API-RP45), ASTM D3921**

THC (Oil and Grease) was determined according to API-RP45 method using a Spectrophotometer. The sample was extracted twice with 1: 10 ratios of Xylene to sample. The combined extract after centrifuging was read in the spectrophotometer using Xylene as the reference material. The spectrophotometer had been previously calibrated with crude oil. Readings obtained from the spectrophotometer were traced out on the calibration graph and used to calculate the concentration of THC (Oil and Grease) in mg/l AP1, (1990), (ASTM, 2015), USEPA, (2014).

## RESULTS AND DISCUSSIONS

### Characterization of Oily Wastewater Properties

| S/N | PARAMETER | MAXIMUM/PEAK VALUE | MEAN VALUE | MINIMUM VALUE |
|---|---|---|---|---|
| 1 | Temperature ( $^0$C ) | 20.00 | 19.12 | 18.31 |
| 2 | Specific Gravity of Water | 0.994 | 0.990 | 0.986 |
| 3 | Specific Gravity of Oil | 0.873 | 0.859 | 0.845 |
| 4 | Dynamic Viscosity Of Water, µ (N/m$^2$.s) | 0.00127 | 0.00130 | 0.00132 |

| S/N | PARAMETER | MAXIMUM/PEAK VALUE | MEAN VALUE | MINIMUM VALUE |
|---|---|---|---|---|
| 1 | pH | 8.80 | 8.65 | 8.50 |
| 2 | Conductivity (µS/cm) | 215.0 | 209.5 | 204.0 |
| 3 | Total Dissolve Solid (mg/l) | 165.50 | 162.29 | 159.58 |
| 4 | Total Suspended Solid (mg/l) | 64.41 | 63.10 | 61.79 |
| 5 | Salinity as Chloride (mg/l) | 40.13 | 38.80 | 37.46 |
| 6 | Oil and Grease (mg/l) | 46.80 | 44.10 | 41.40 |
| 7 | Biological Oxygen Demand (mg/l) | 31.0 | 29.92 | 28.83 |
| 8 | Chemical Oxygen Demand (mg/l) | 43.58 | 41.90 | 40.21 |

## DISCUSSIONS

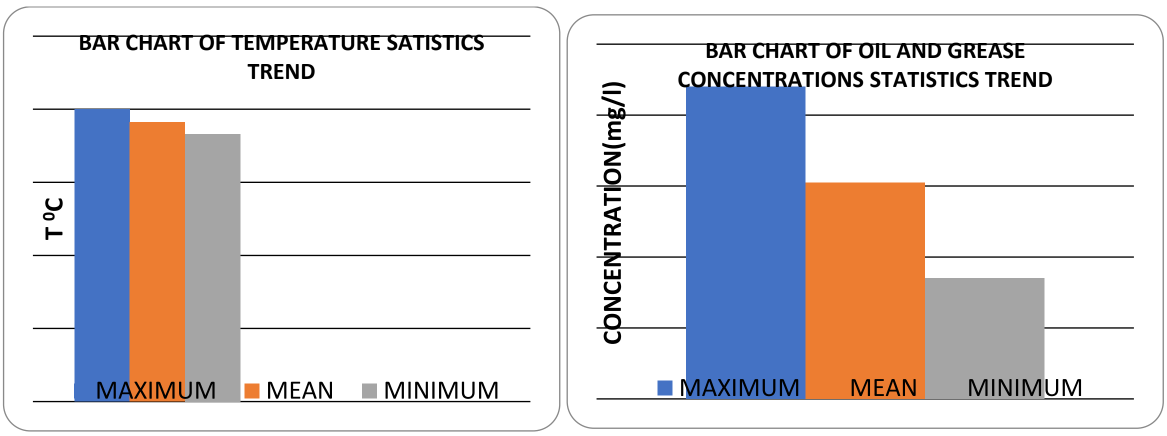


**FIG 1: Bar of Oil and Grease at A Given**

## Temperature

The bar chart in figure 1 above shows the ranges of oil and grease at a given temperature. From the bar chart above it showed that oil and grease concentration ranges from 46.80 to 41.40 mg/l.

The oil category (free, emulsified, or dissolved) will establish the type(s) of separator system(s) required, this can be determine through conduction of bench scale studies in the laboratory, Free oil will be defined as that which is separable by gravity in a reasonable time period, normally a few hours. As temperature increases velocity increases, the period of time and size of separation chamber will be decreased for a given flow rate. For gravity separation, the primary concern is free oil and grease because gravity separators are not effective in removing emulsified or dissolved oils.

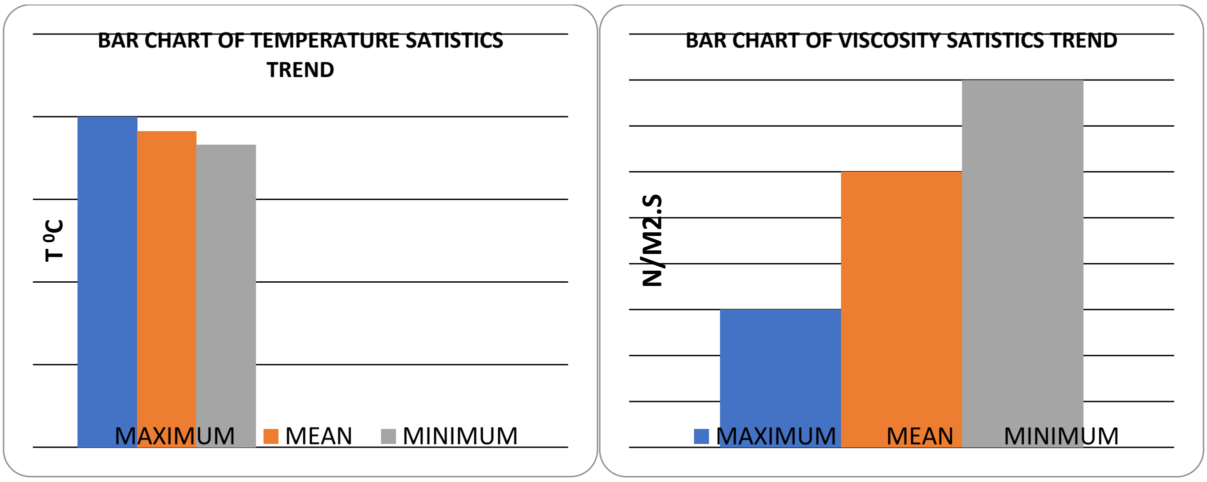


**FIG 2: Bar Chart of Temperature and Viscosity Trend**

From the bar chart above, the temperature ranges between 20.0 to 18.31$^0$C. The maximum temperature is 20$^0$C while the minimum temperature is 18.31$^0$C. Also, the viscosity at maximum temperature is 0.00127N/m$^2$.s, while at minimum temperature is 0.00132N/m$^2$.s. Wastewater temperature has a major impact on the efficiency of the separator. Temperature affects oil viscosity. The lower the oil viscosity (higher temperature), the faster the rise velocity of the oil. The lower the temperature the more difficult separation will be, therefore, the lowest temperatures should be used in sizing the separator. In general, a conservative temperature value within the range is (19.16 - 18.31 $^0$C should be use).

African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 3, Issue 4, 2020 (pp. 1-11)
www.abjournals.org

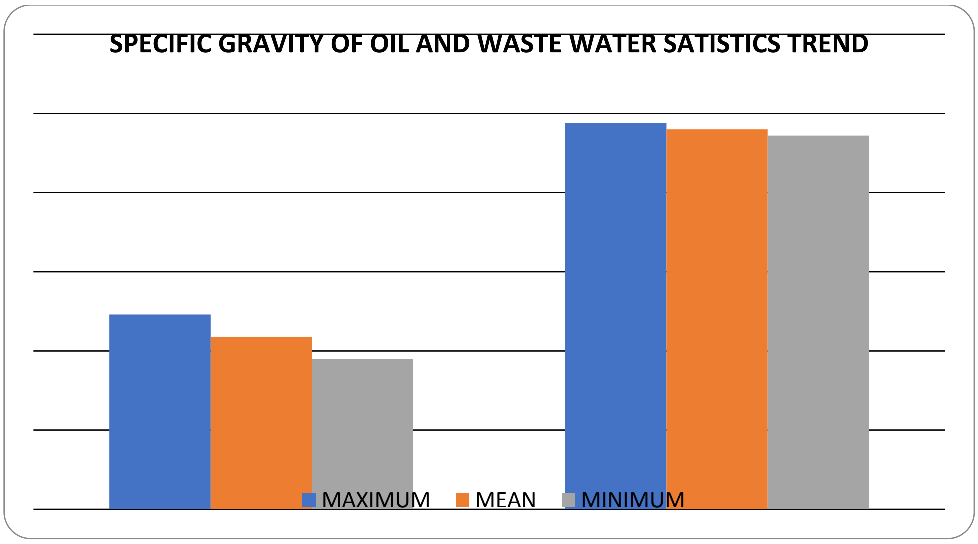


**FIG 3: Bar Chart of Specific Gravity of Oil and Wastwater at Maximum Mean and Minimum Value**

The bar chart above depicts the specific gravity of oil and wastewater at operating temperatures. It shows that specific gravity of oil at operating temperatures ranges between 0.873 to 0.845 while that of wastewater at operating temperatures ranges between 0.998 to 0.996. Wastewater Oil-fraction Specific Gravity (at minimum design temperature of $18.31^{0C}$) is 0.845. The greater the difference in specific gravity between the oil and water, the more efficient separation will be. From the strokes' law: as the diameter of particles increases, velocity increases, also as temperature increases, velocity increases, and also the higher difference in specific gravity increase, velocity increases. Obviously, as the terminal velocity increases, the period of time and size of the separation chamber will be decreased for a given flow rate.

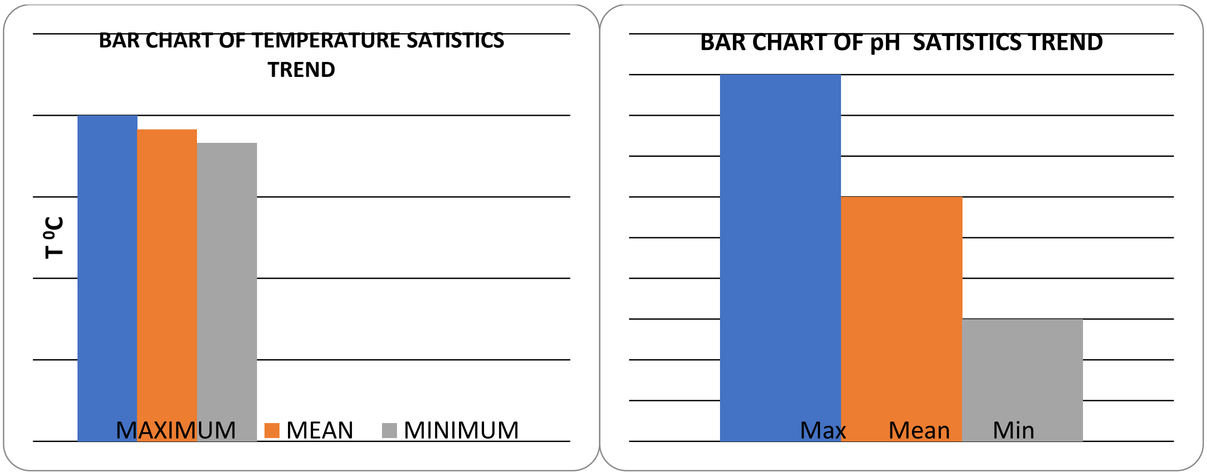


**FIG 4: Bar Chart of Temperature and pH Trend**

The bar chart from figure 4 shows the trend of pH at a particular temperature. Which ranges from 8.80 to 8.50. The pH of the wastewater affects oil removal efficiency. If the wastewater is alkaline (pH above 9.0), some oils may become more soluble. If the wastewater is alkaline (pH above 9.0), then additional treatment beyond gravity separation will be required. From characterization pH is between 8.80 – 8.50) is within the limit, this may not require further treatment.

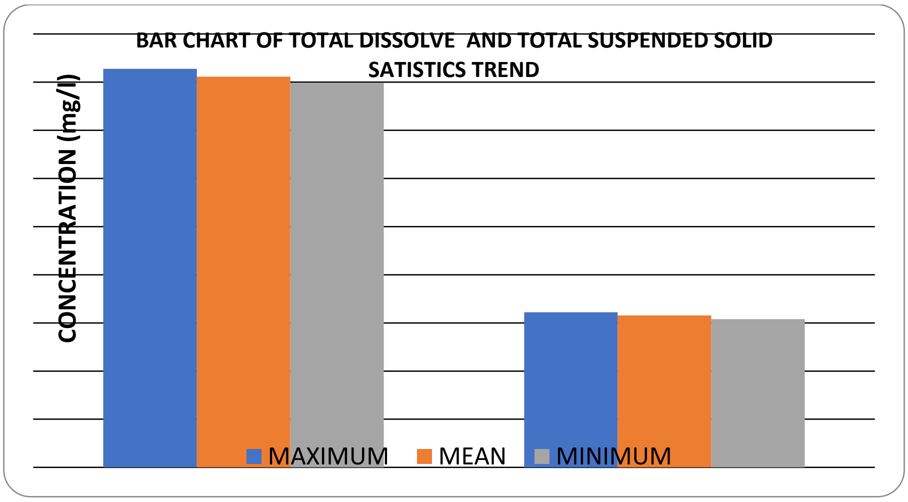


**FIG 5: Bar Chart of Total Suspended Solids and Total Dissolve Solids**

The result of statistical analysis from figure 5 shows that total suspended solids ranges from 64.41 to 61.79mg/l while total dissolve solid is between 165.50 to 159.58 mg/l This analysis provides an indication of the amount of settled materials that will have to be removed from the separator Stokes Law has historically been used as a basis for understanding the principles of and significant factors impacting separation of settleable solids from wastewater by gravity. Therefore, the solids content of the wastewater is important in overall system design. Total suspended solids are the non-dissolved portion, retained on a filter, of total solids. Settleable solids is the term applied to material settling out of suspension within a defined period. This characterization helps to determine the amount and frequency of settled materials that will need to be removed from the bottom of the oil-water separator and the advisability of providing grit removal upstream of the oil water separator.

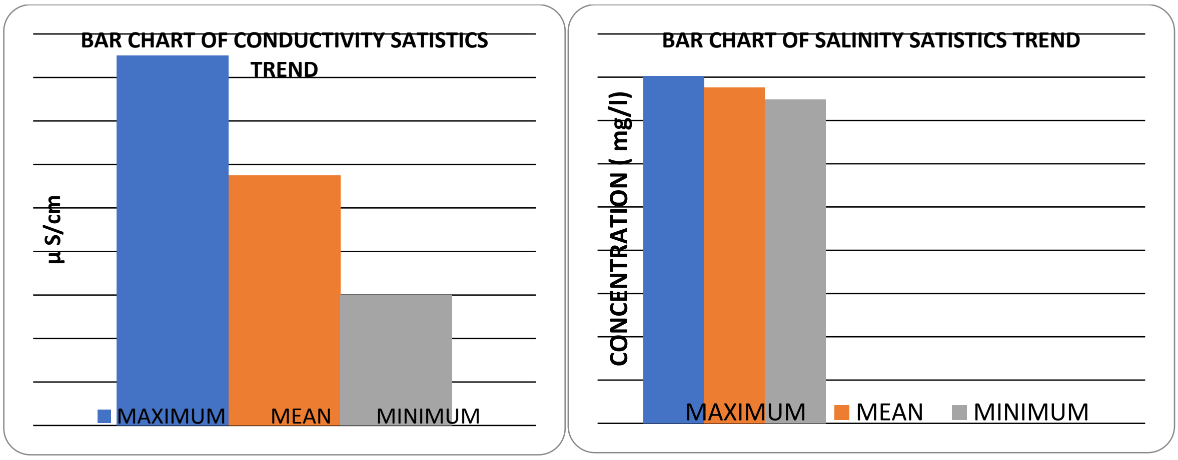


**FIG 6: Bar Chart of Conductivity and Salinity as Chloride**

From figure 6 above, the conductivity and salinity as chloride range from (215.0 – 204.0 µS/cm) and (40.13 – 37.46 mg/l) Salinity is an indication of the dissolved salt content of the wastewater. One indicator measurement method of salinity is conductivity, which measures the ability of an aqueous solution to carry an electric current. Increased salinity (seawater) increases the specific gravity and absolute viscosity of the water. This gives an idea on the rise of terminal velocity.

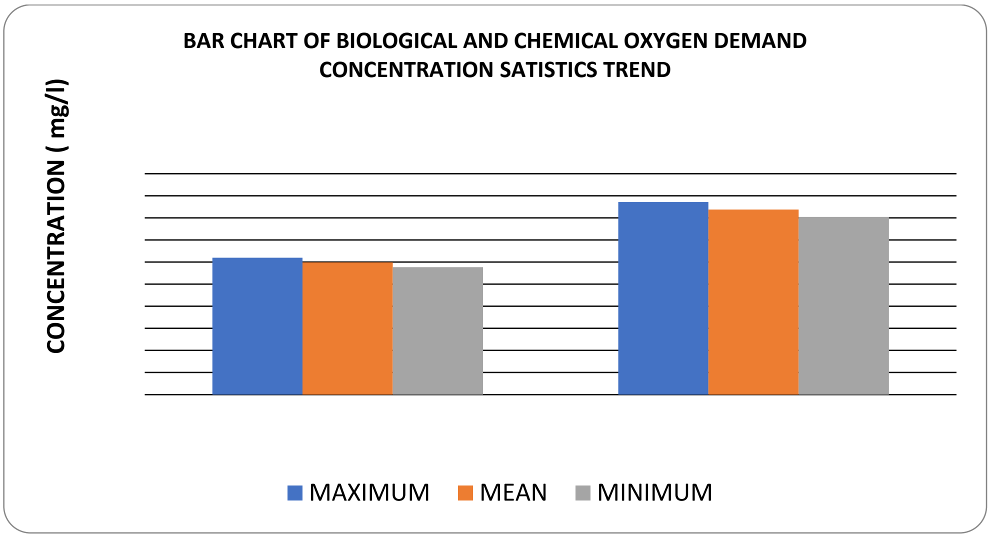


**FIG 7: Bar Chart of Biogical Oxygen Demand and Chemical Oxygen Demand Trend**

Figure 7 above shows the trend of biological and chemical oxygen demand also ranges from ( 31.00 – 28.83 mg/l) and ( 43.58 – 40.21 mg/l) Biochemical oxygen demand is an important water quality parameter also because it provides an index to assess the effect discharged wastewater will have on the receiving environment. The higher the Biological Oxygen Demand value, the greater the amount of organic matter or "food" available for oxygen consuming bacteria. If the rate of Dissolved Oxygen consumption by bacteria exceeds the supply of Dissolved Oxygen from aquatic plants, algae photosynthesis or diffusing from air, unfavorable conditions occur. Depletion of Dissolved Oxygen causes stress on aquatic organisms, making the environment unsuitable for life. Further, dramatic depletion can lead to hypoxia or anoxic environments, fouling of coalescing plate.

Chemical Oxygen Demand is an important water quality parameter because, similar to Biogical Oxygen Demand, it provides an index to assess the effect discharged wastewater will have on the receiving environment. Higher Chemical Oxygen Demand levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in Dissolved Oxygen can lead to anaerobic conditions, which is deleterious to higher aquatic life forms. These characterizations will also help in advisability of providing the nature of maintenance to be carried out in oil-water separator.

## CONCLUSION

The design of oil-water separators should carefully consider these characteristics of the wastewater and the oil itself since its characteristics varies from one region to another. With this characterization the design information will be established. Overall, oil-water separation system designs are characterized and recommendations for ensuring system efficiency, regulatory compliance, reliability and sustainability.

## REFERENCES

A.P.H.A., (2015): Standard methods for the examination of water and wastewater. 15th edition. American Public Health Association, American water Works Association and Water

American Petroleum Institute (API), (1990). Gaussian Dispersion models applicable for Refinery emissions. API Publication 51.

American Standard Testing and Materials (ASTM), (2015) Water and Environmental Technology, vols. I and II.

Ashraf, M.A., Shafiq, U., Mukhtar, A., & Saeed, M.M., 2015. Design of industrial gravity type separators for the hydrocarbons and heavy oil-water separations. Research Journal. Chemistry Science, 5 (9), 72–75.

Department of the Army, U. S. Army Corps of Engineers, (DA USACE) (2014). Engineering Technical Letter, Selection and Design of Oil/Water Separators At Army Facilities.

DPR (1991): Environmental guidelines and standards for the petroleum industry in Nigeria. Department of Petroleum Resources, Ministry of Petroleum and Mineral Resources, Lagos.

HACH, (2005). Hach Company, Direct Reading (DR)/3000 spectrophotometer Manual. DR/2010 spectrophotometer Handbook (2001).

Managi, S., Opaluch, J.J., Jin, D., & Grigalunas, T.A., (2015). Environmental regulations and technological changes in the offshore oil and gas industry. *Land Econ*. 81 (2), 303–319.

Methods for Chemical Analysis of Water and Wastes" (2013) (EPA-600/4-79-020), U.S. Environmental Protection Agency, Washington, D.C

Mohr, K.S., &Veenstra, J.N., 2000. Albuquerque, New Mexico. In: Proceedings, International Petroleum Environment Conference: An Overview of US an International Regulations Regarding Hydrocarbons in Water Effluents.

Tom Schultz (2011) Siemens water Technologies Pollution Control Federation, Washington, ND.C.

Tom, S. (2015). Industrial Oily Wastewater Pretreatment (Siemens water Technologies)

United State Environmental Protection Agency (USEPA) (2014). National Exposure Research Laboratory Manual Reference Method.